Evaluation of VTO Benefits (BaSce)

2015 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

June 9th, 2015

Neeraj Shidore, Namdoo Kim, Aymeric Rousseau

Argonne National Laboratory

Sponsored by David Anderson, Jacob Ward & Fred Joseck

Project ID # VSS_164

Project Overview

Timeline	Barriers*
Start Date: October 2014 End Date: October 2015 Percent Complete: 90%	• Risk aversion • Constant advances in technology • Cost • Computational models, design, and simulation methodologies *from 2011-2015 VTP MYPP
Budget	**Partners**
Total Project Funding (FY15) • $250,000 (Dave Anderson) • $250,000 (Jacob Ward) • $125,000 (Fred Joseck)	Formal Collaborator • All USDrive Partners Interactions • All USDrive Partners, outside companies (OEMs, suppliers…)

Relevance

CAFE
Fuel Economy Standards

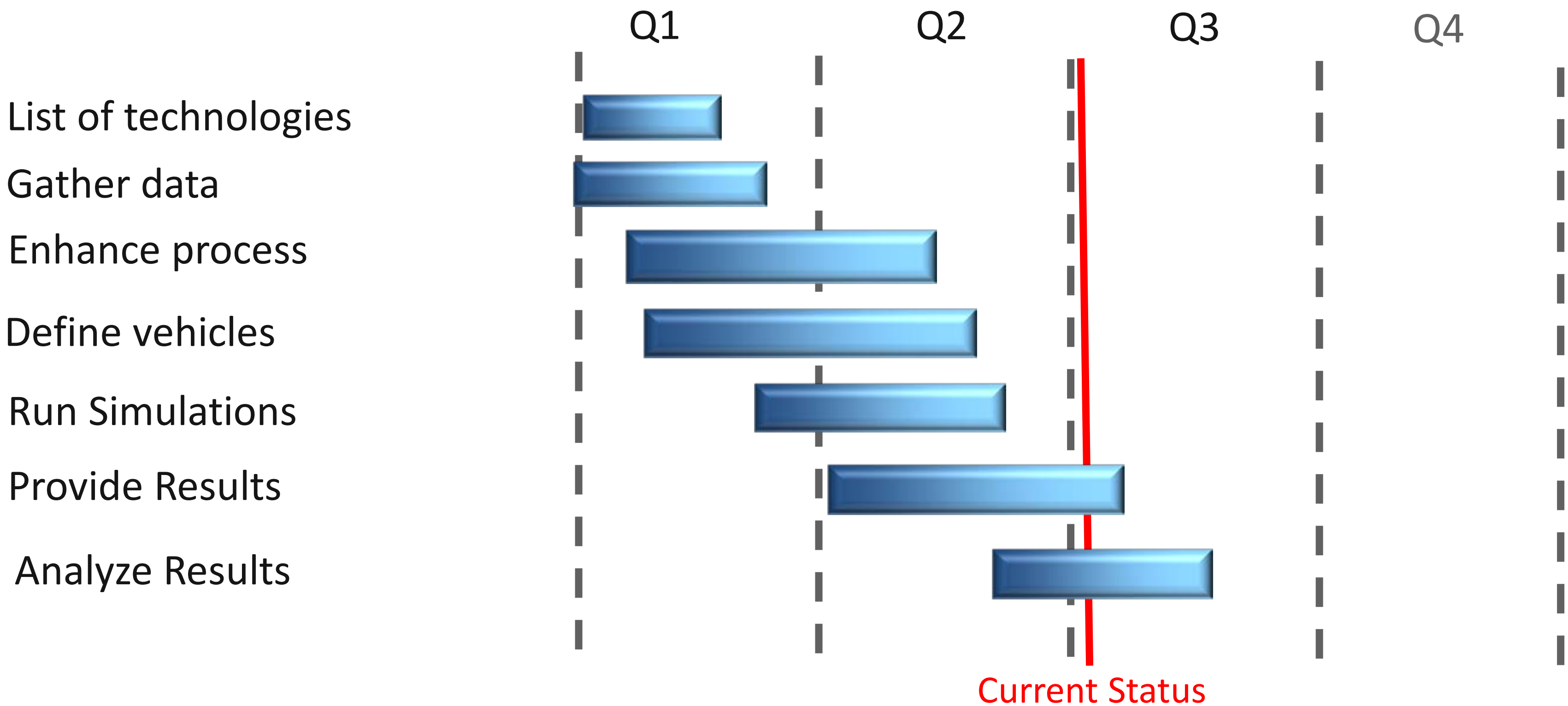
Baseline

Additional
Improvements

Mandated
by
Congress

- What are the benefits of the USDrive Partnership in terms of petroleum displacement?
- How much additional petroleum could be displaced with additional funding?
- Assess technology potential to guide future research and development

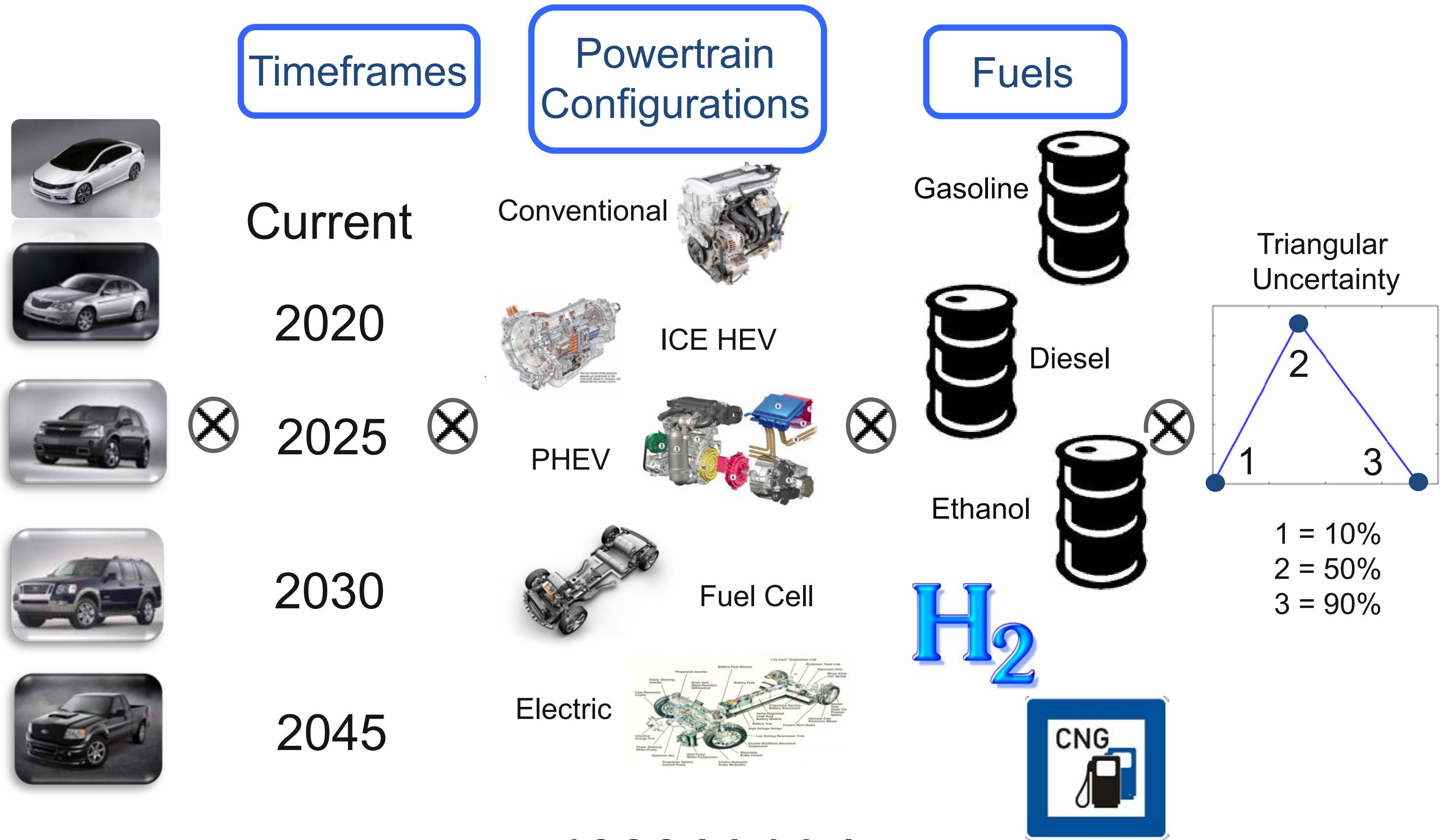
Milestones



Individual reports for each technology and a comprehensive report will be published in Fy2016.

Approach

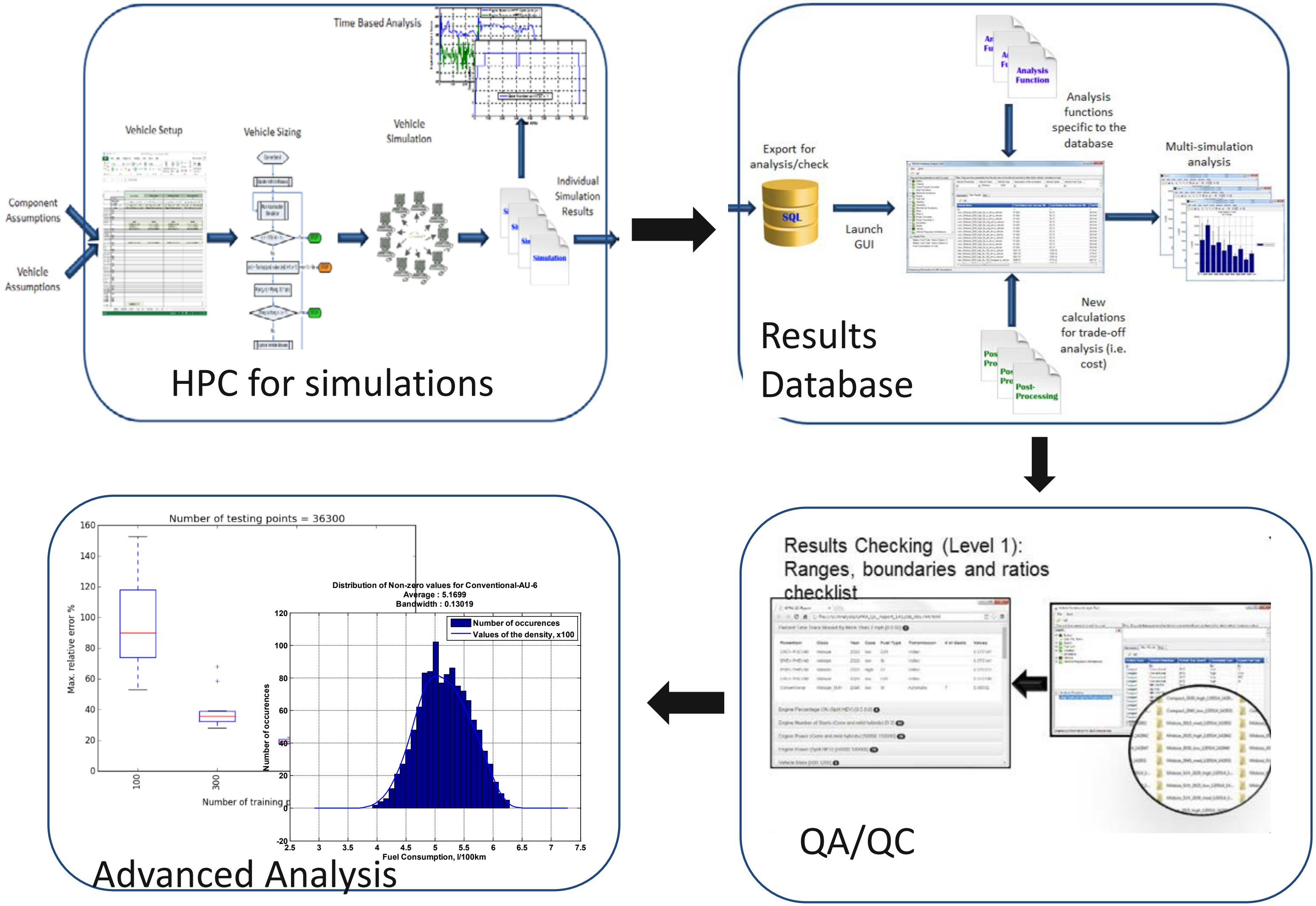
Consider All the Technologies Within DOE VTO / FCTO Portfolio



> 4000 Vehicles

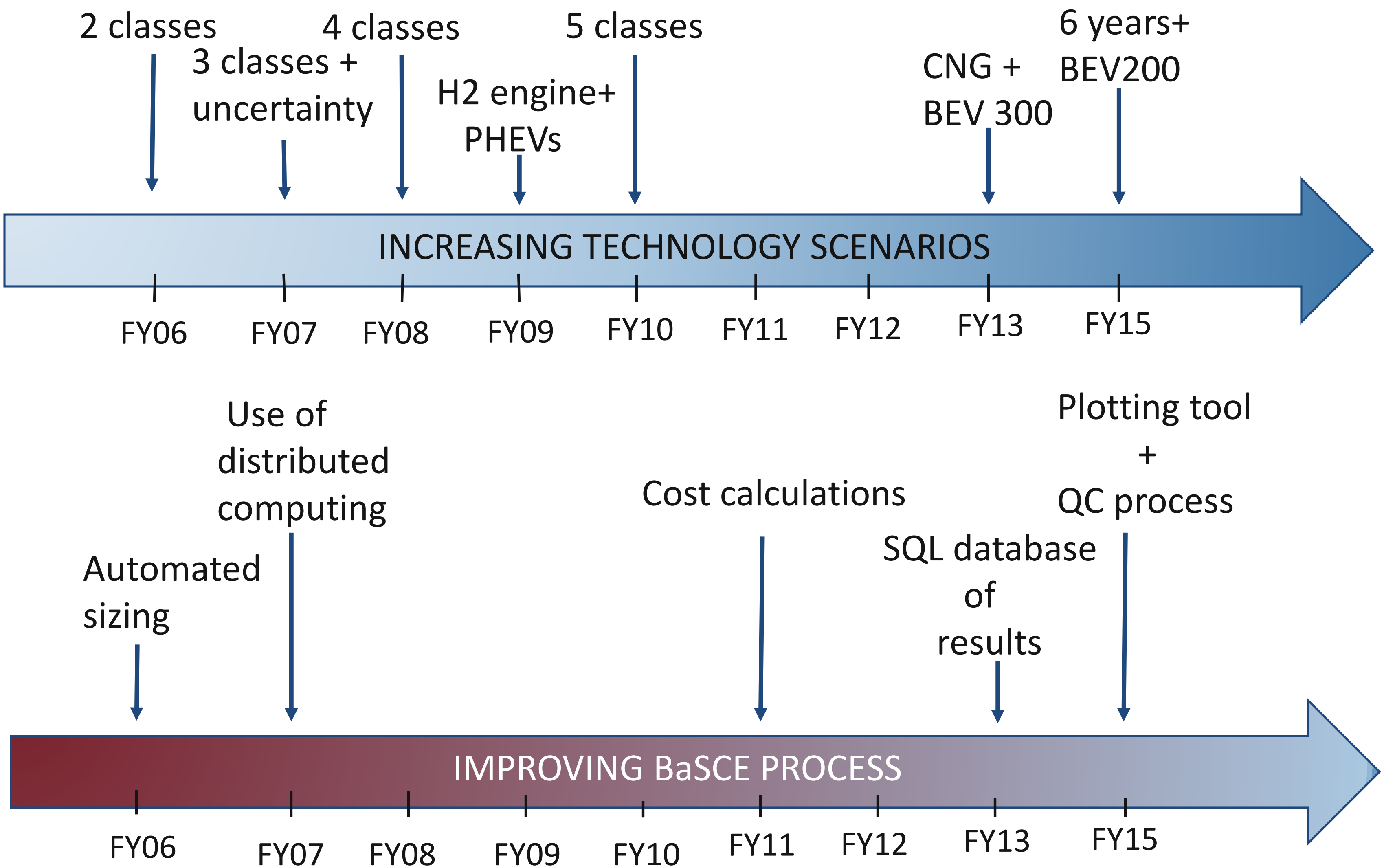
Approach

Leverage MBSE to Enhance the BaSCE process



Approach

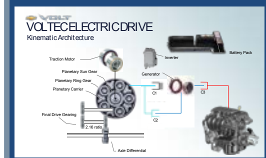
Process Improvement Helps Meet Increasing Technology Scenarios



Approach

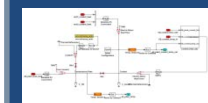
A Very Large Number of Studies Feed into BaSCE

Vehicle Powertrain



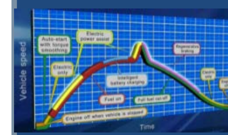
I.e. GM Voltec Development

Component Models



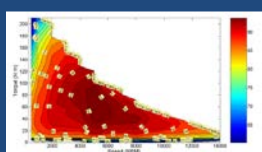
I.e. Advanced Transmission (i.e. DCT)

Vehicle Control



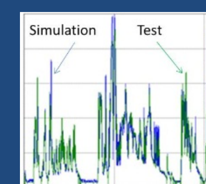
Integrate advanced control algorithms such as instantaneous optimization or route based control

Component Benchmarking



BaSCE

Validation

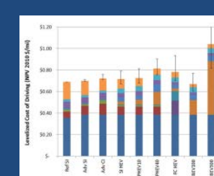


Standard Procedures

Large Scale Simulation

Numerous processes, including vehicle sizing algorithms, distributed computing, parametric study, SOC correction… are used to evaluate a large number of options

Levelized Cost of Driving



Integrate LCD calculations to evaluate the technology benefits using $/mile

Technical Accomplishments

Assumptions -Transmission and Final Drive Ratio Designed to Meet Industry Trends in Engine and Vehicle Operation

- Previously, gear ratios were used from transmissions available in the industry.
- New approach will involve development of gear ratios based on engine operation, vehicle operation and transmission trends in the industry.

APRF: trends in shifting , Engine operation

Literature review, industry trends, expert opinion

USCAR engine benchmarking CRADA- information on engine operation
In a vehicle.

Sample rules for gear ratio and fd:

1. Switch to top gear around 45 mph.
2. Lugging consideration.
3. Number of shifts for UDDS.
4. NVH and low speed , high torque operation.
5. Survey of gear ratios per vehicle class

Select Gear Span , top gear and final drive based on industry trends

↓

Design progressive gear ratios

↓

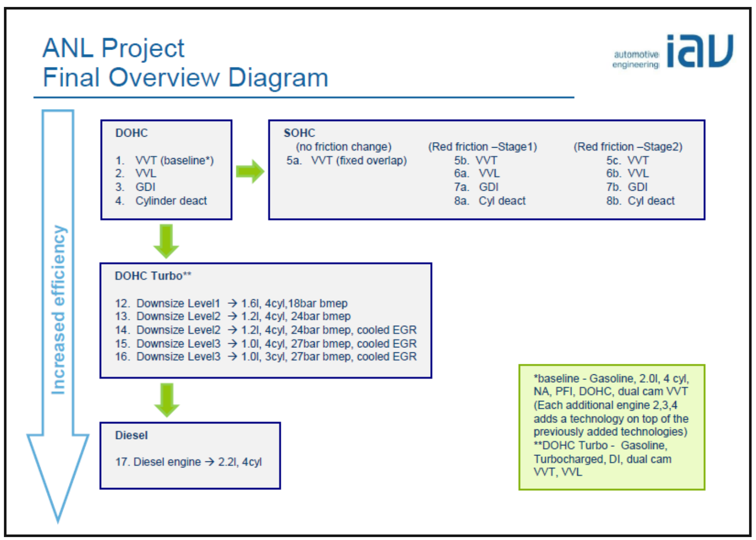
Ensure that selected gear ratios meet engine operation requirements and fuel economy performance relationship between different transmission types

Technical Accomplishments

Assumptions -Engine Technology Assumptions tied to GT Power Maps

Efficiency Assumptions defined by DOE

Parameter	Current		2015			2020			2025			2030			2045		
		Current	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
GASOLINE for Conventional																	
Engine mass reduction		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aftertreatment Eff Penalty		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IC Engine eff		0.36	0.37	0.38	0.4	0.38	0.42	0.45	0.39	0.435	0.46	0.4	0.45	0.47	0.42	0.47	0.5
Cost																	
Materiel		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cylinder Deac		0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
Variable Valve Lift		0	0	0	1	0	1	1	0	1	1	1	1	1	1	1	1
Variable Valve Timing		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
HCCI		0	0	0	0	0	0	1	0	0.5	1	0	1	1	1	1	1
Direct Injec		0	0	1	1	0	1	1	0.5	1	1	1	1	1	1	1	1
Boost		0	0	0	1	0	0	1	0.5	0.5	1	1	1	1	1	1	1

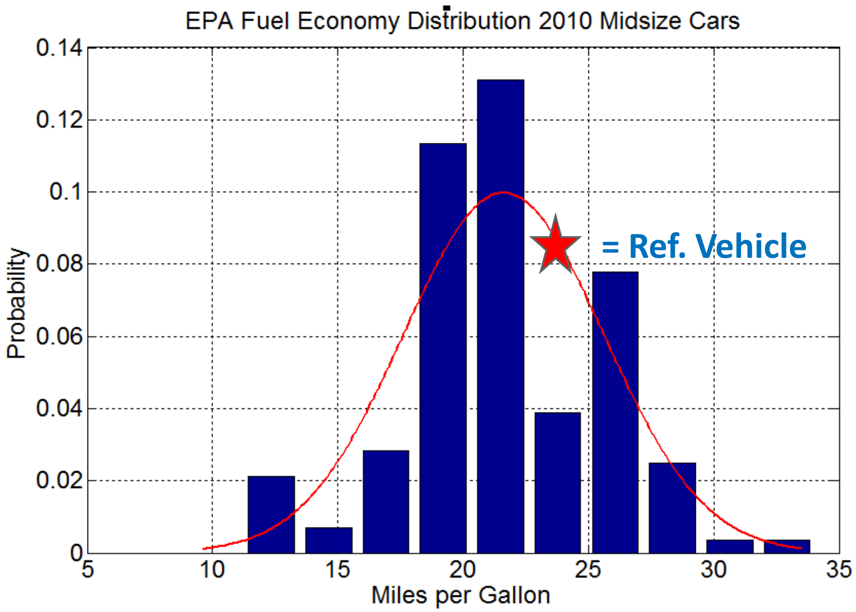


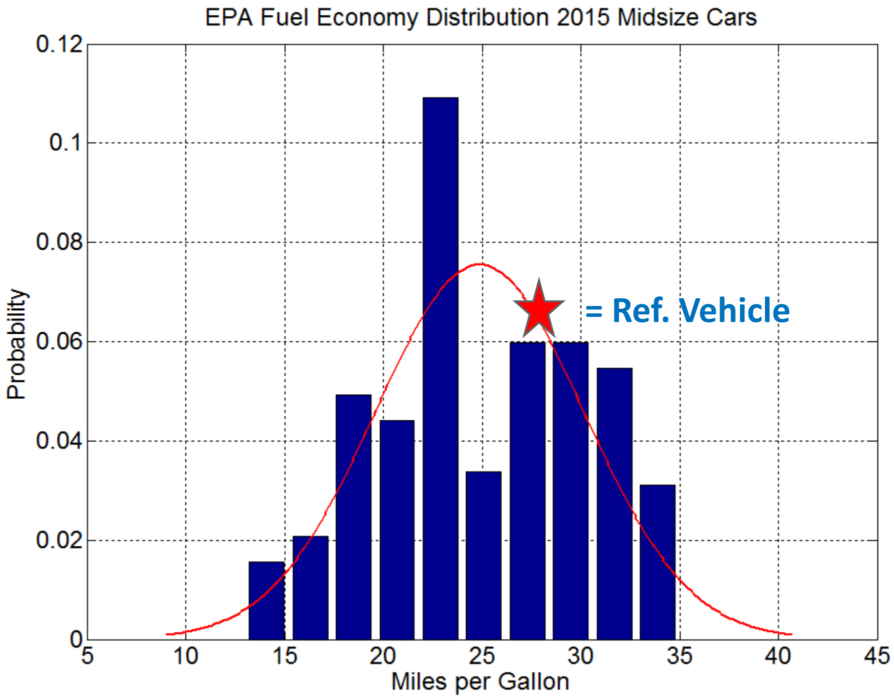
Identify technology from IAV maps (e.g. cylinder deac, VVL, friction reduction, turbo etc) that is close to DOE targets

GT power based bsfc maps used for DOE study on impact of advanced engines

Technical Accomplishments

Assumptions: Baseline Vehicles Updated based on Industry Trends

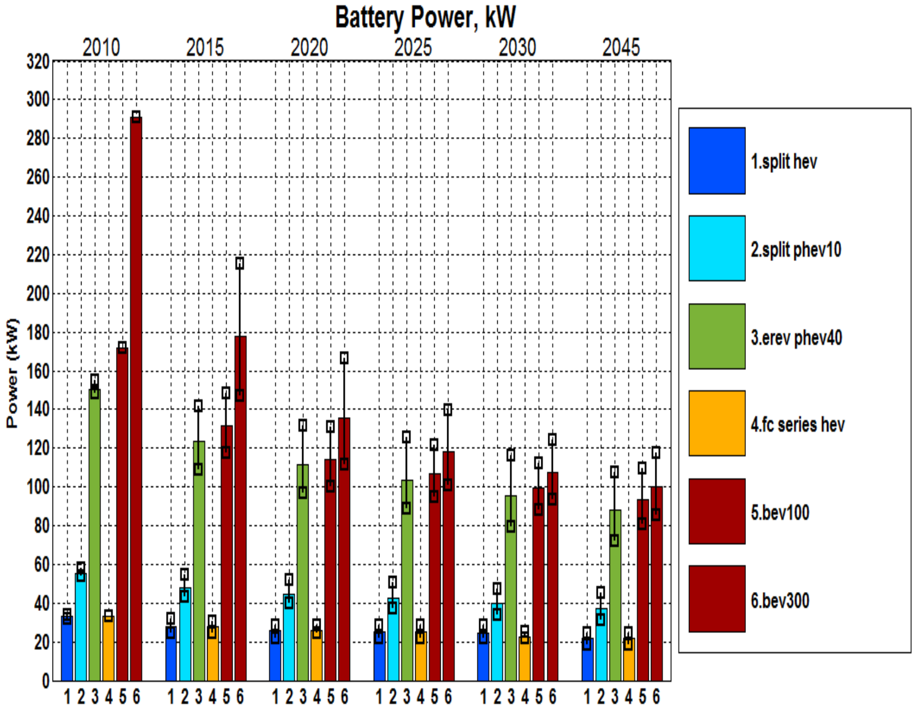


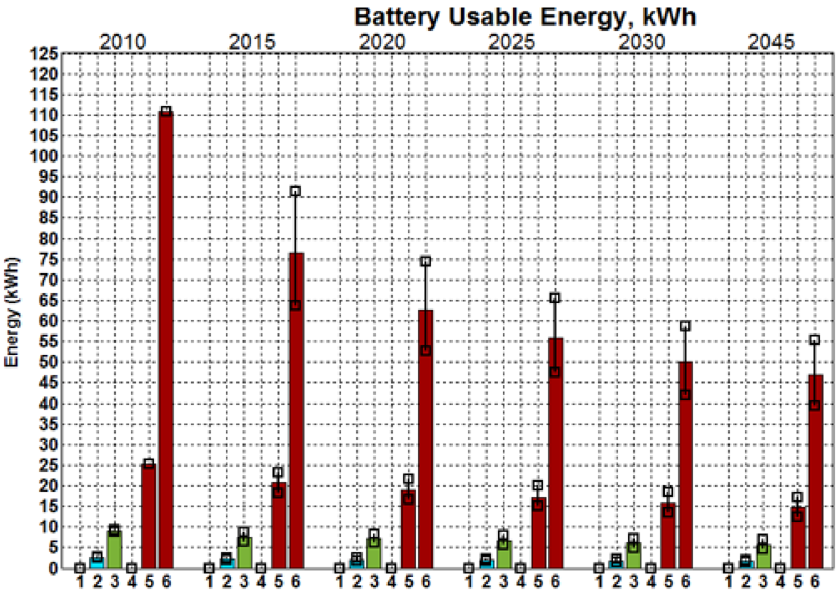


Technical Accomplishments

Component Sizing- Battery Power and Energy Requirements to Meet VTS Decrease Significantly over Time.

- Battery peak power and total energy are expected to decrease significantly due to higher energy density, other component improvements as well as a wider usable SOC range. The energy required for BEV 300 could be reduced by 55%, and power by 65%.



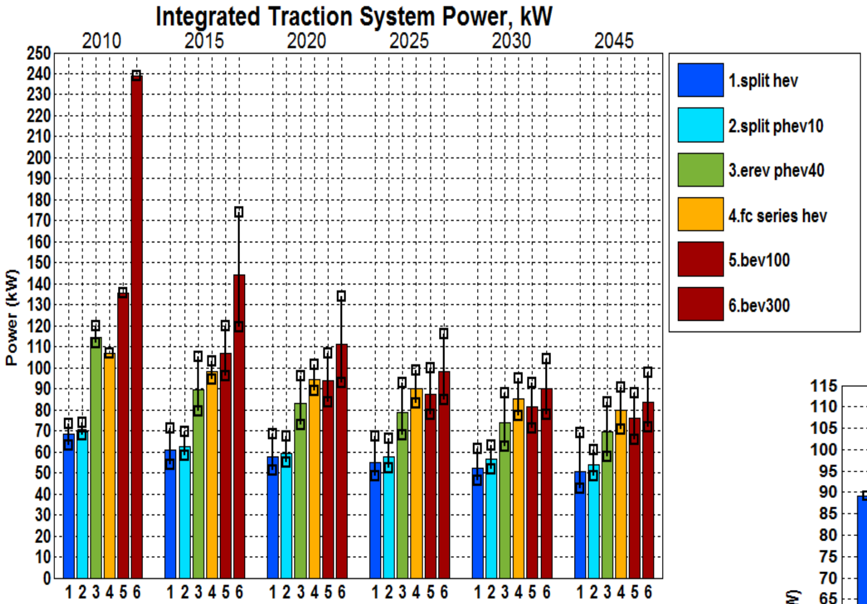


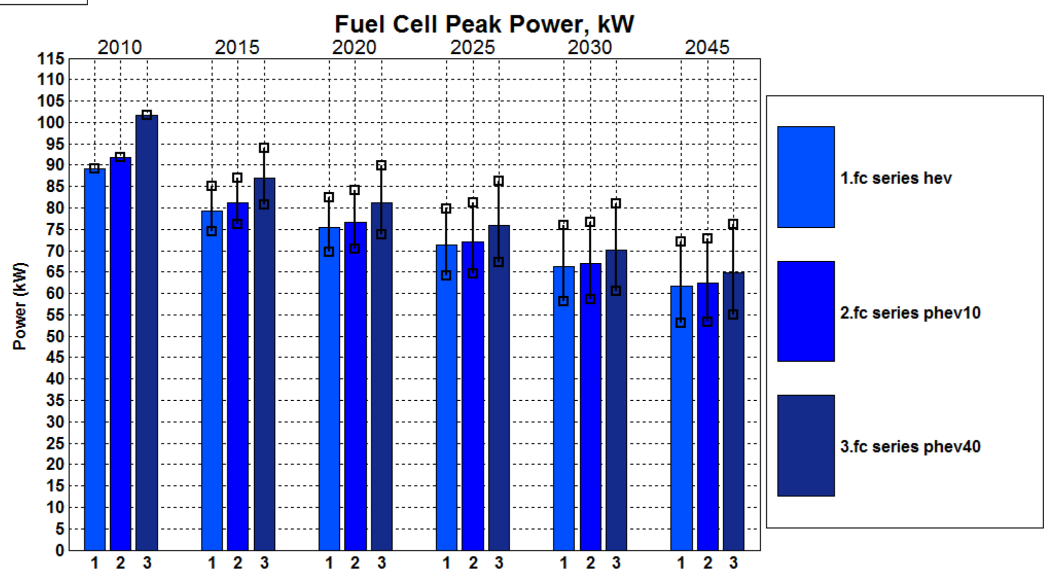
Both plots for midsize vehicles

Technical Accomplishments

Component Sizing – High Voltage Traction System and Fuel Cell Power Also Significantly Decrease in the Future.

- With light weighting and improvement in component technology, High Voltage Traction System and Fuel Cell Power required to meet VTS decrease with time.



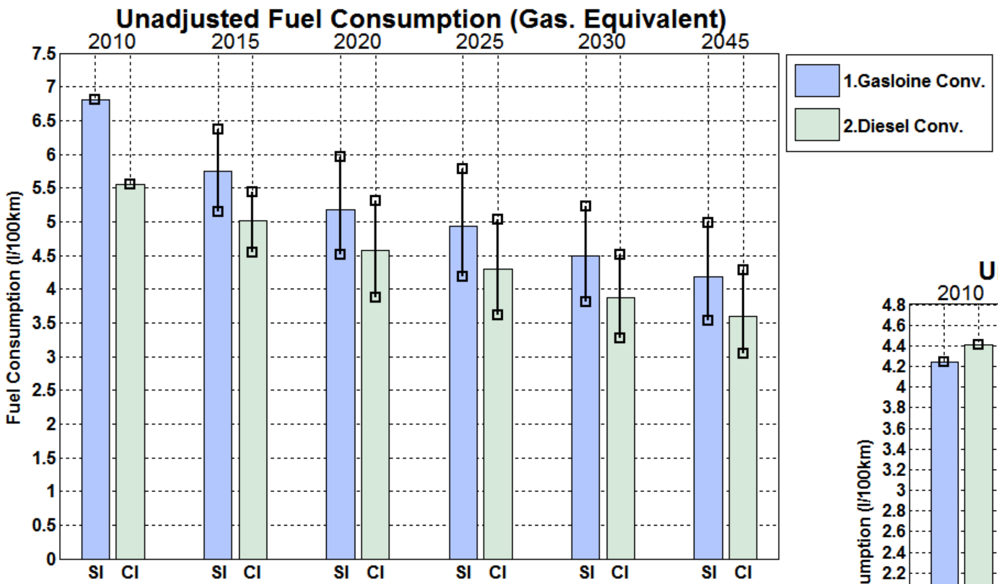


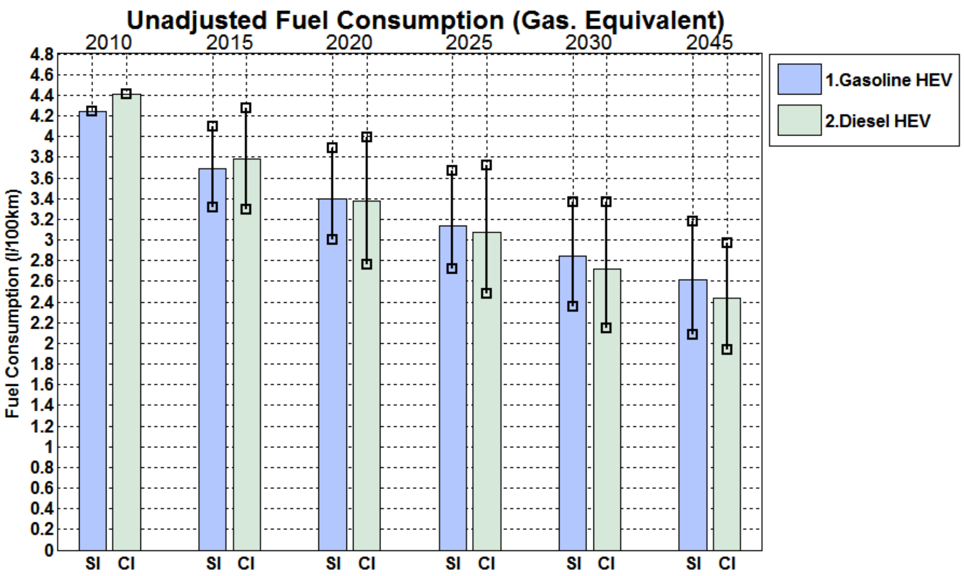
Both plots for midsize vehicles

Technical Accomplishments

Energy Consumption: Gasoline Technology Competitive with Diesel in the Future

- With improvement in gasoline technology in the future, gasoline HEVs have better FE than diesel HEVs.

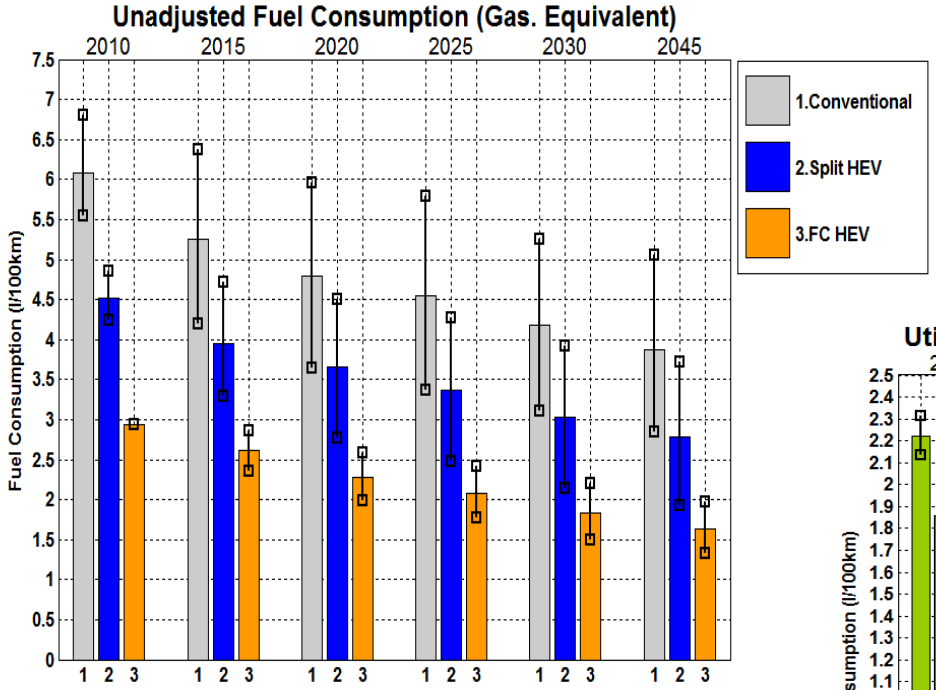


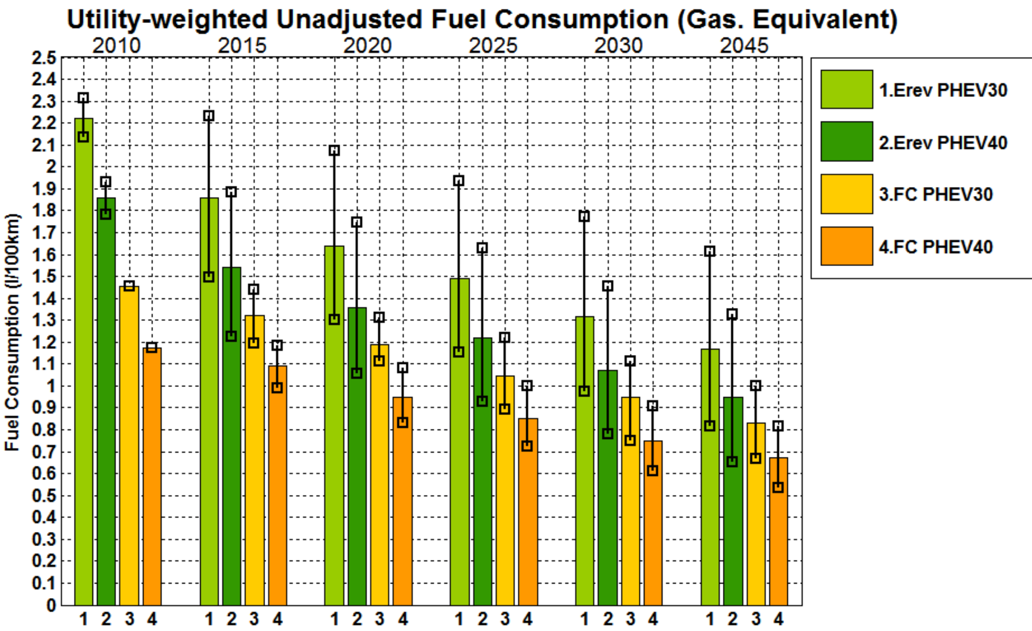


Both plots for midsize vehicles

Technical Accomplishments

Energy Consumption: Fuel Cell Vehicles have Lower Fuel Consumption across all Electrified Powertrains (mpgge basis)

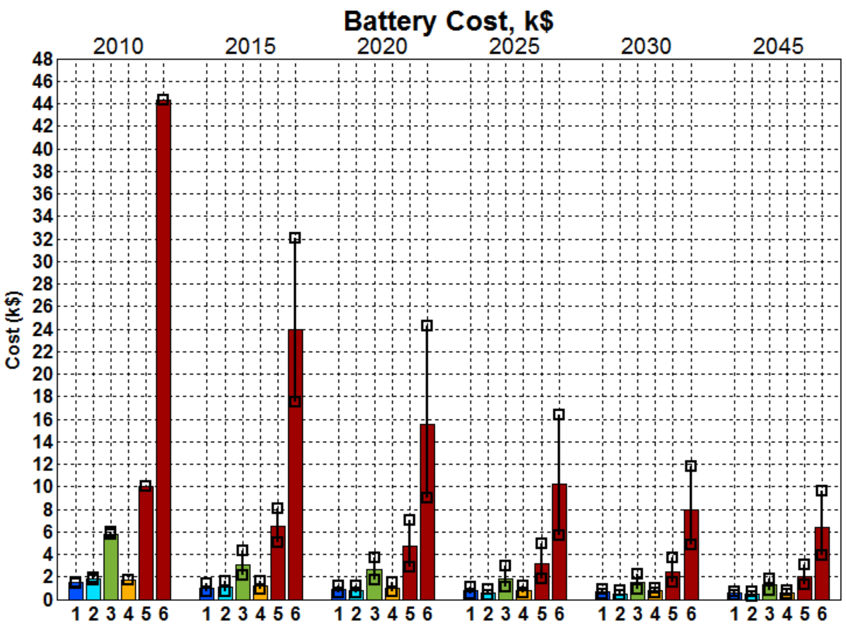




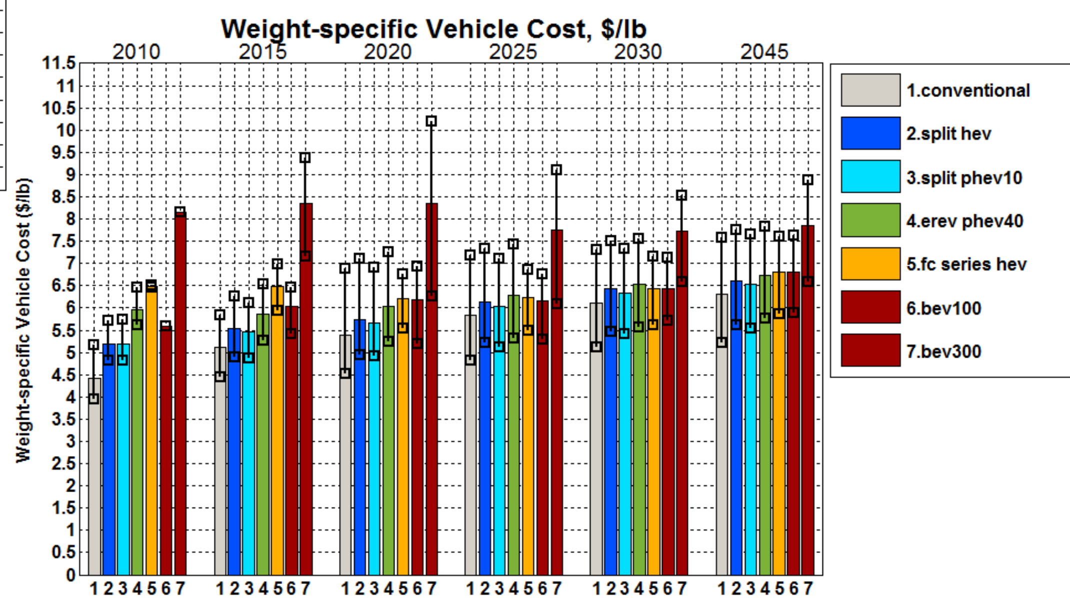
Both plots for midsize vehicles

Technical Accomplishments

Manufacturing Cost: Battery Cost decreases Significantly , but BEVs remain most Expensive



- With significant decrease in battery power and energy requirements, battery cost shows a significant decrease with time, but the BEV-300 still has the highest weight specific vehicle Cost ($/lb)

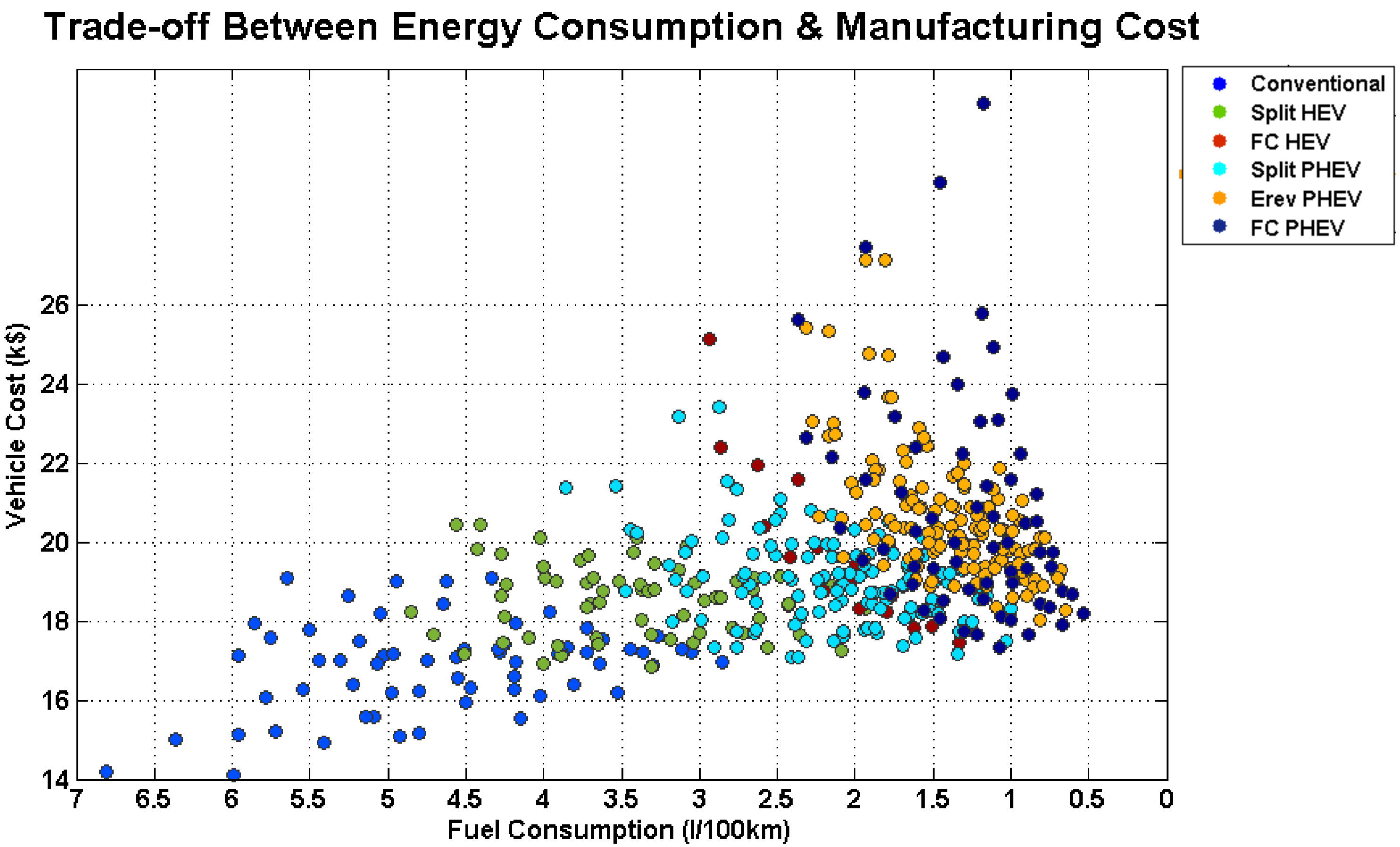


Both plots for midsize vehicles

Technical Accomplishments

Cost and Fuel Consumption Trade off

- PHEVs provide the most fuel consumption benefits, but remain most expensive , within all powertrains with duel fuel source.



Response to Previous Reviewer Comments

Comment in the 2014 evaluation – Vehicle Analysis Section:

‘The reviewer urged care that all assumptions underlying provided data and employed by model users be understood and made explicit’.

A detailed report will be published in Fy16 stating all the assumptions and results explicitly. All the assumptions are currently stored in a single file.

‘The reviewer was left with the impression that the model, and the results from the model, will be for internal use only’

The report published in FY16 will also outline explanation of the vehicle/component model along with the data assumptions and results.

‘this reviewer expressed concern that it will be hard to keep track of all the assumptions with so many data points’

The database tool has been developed in an attempt to help the user manage assumptions and results.

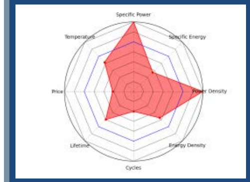
Collaboration and Coordination with Other Institutions

Assumptions, Data

BaSCE

Same Process used to define USDrive Targets

Program Targets



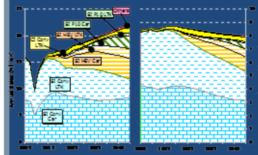
Develop and validate the performance (i.e. power, energy) and cost target of components

Energy Consumption, Cost

Life Cycle Analysis

GREET uses Autonomie outputs to predict GHG, CO2eq…

Market Penetration



Models like MA3T and Vision use outputs from Autonomie

Report available online used by numerous researchers

Future Work

FY15 On going work

- Provide results to market penetration and life cycle analysis (LCA) tools to evaluate VTO technology benefits .
- Continue to refine results and add additional results parameters as needed by LCA and market penetration tools.

FY16 Activities

- Detailed analysis to understand impact of VTO technology on each component (power, energy, weight).
- A comprehensive report on light duty fuel consumption displacement potential for light duty vehicles due to VTO technology.

Proposed Future Work

- The process would be repeated to evaluate the impact of individual technology , e.g.
  - Evaluate benefits of battery technology by keeping engine, fuel cell, transmission , light-weighting technology at present day status.
  - Evaluate fuel consumption and cost sensitivity to light weighting for future vehicles.

- The process can be extended to MD and HD vehicles, to better support Life Cycle Cost Analysis (LCA) and VTO technology impact in these segments.

Multi-year Vision

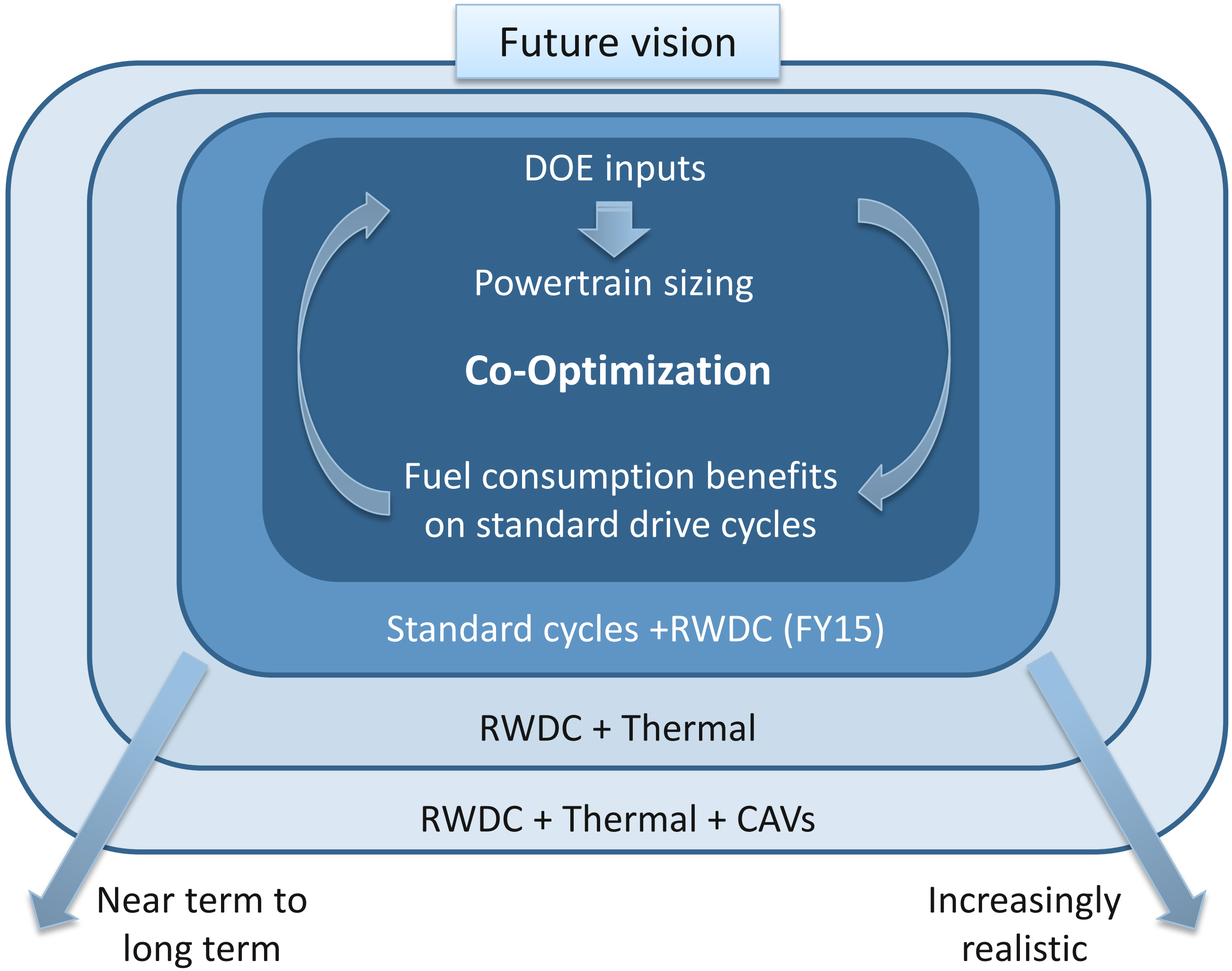
Incorporate multiple scenarios (RWDC, thermal, CAVs) for VTO technology evaluation

Current Approach

DOE inputs

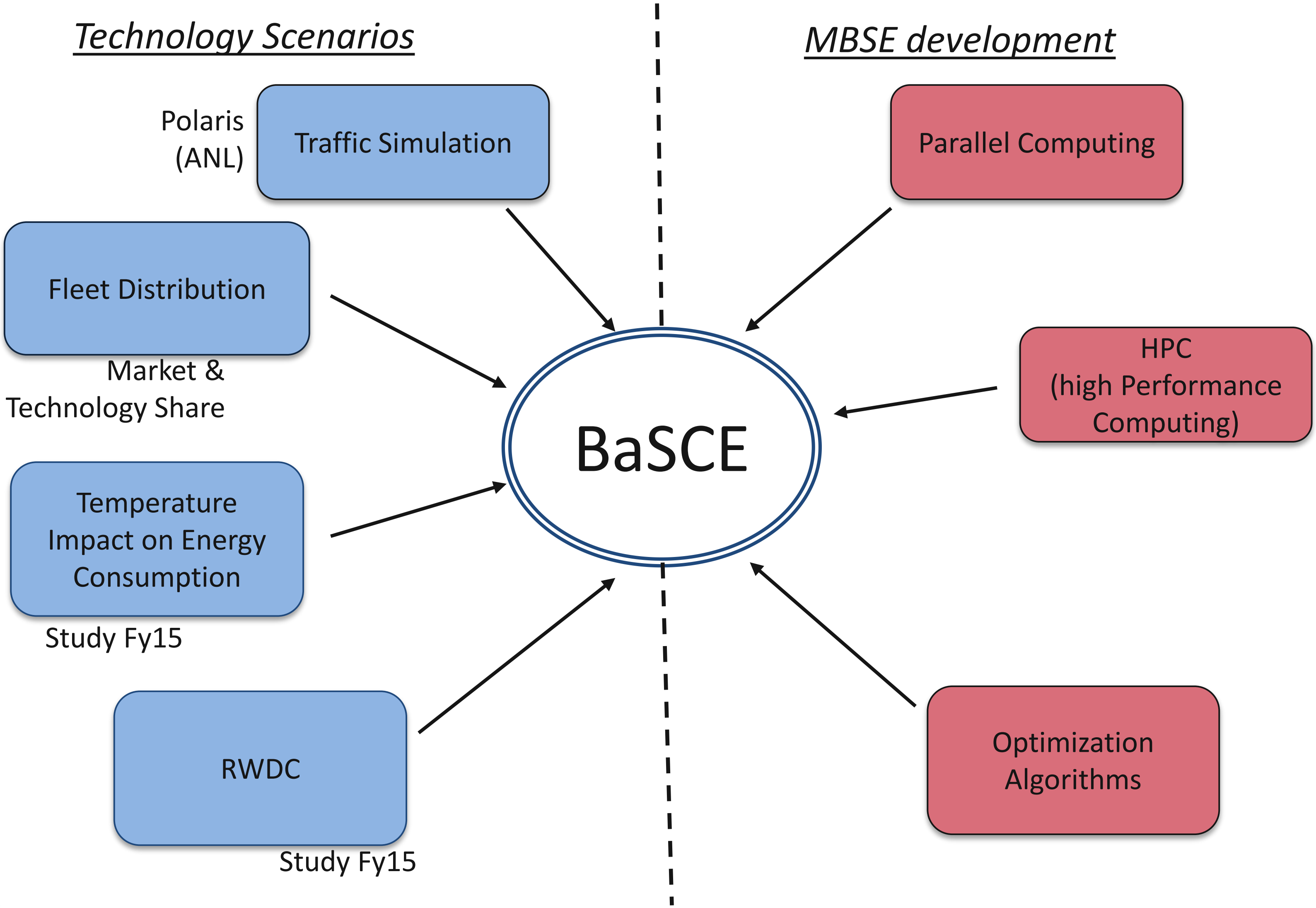
Powertrain sizing based on rules (reviewed by VSATT)

Fuel consumption benefits
on standard drive cycles
with rule based
(fixed para values)
Control.



Expanded scenarios for realistic evaluation of VTO technology

BaSCE will Leverage MBSE and other Studies to Cover the Expanded Scenarios



Summary

- The BaSCE study evaluates the benefits of the VTO technologies in terms of petroleum displacement and cost.
- The study assesses technology potential to guide future research and development by evaluating the benefits of the latest technologies both from a component and a control point of view.
- More than 4000 vehicles were simulated for different timeframes (up to 2045), powertrain configurations, and component technologies.
- Both energy consumption and cost were assessed to estimate the potential of each technology. Each vehicle was associated with a triangular uncertainty.
- The processes developed for the study along with its results are used to support numerous activities within DOE.